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SOME RELATIONSHIPS BETWEEN 850-MILLIBAR LOWS AND HEAVY SNOW OCCURRENCES OVER THE CENTRAL AND EASTERN UNITED STATES

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ABSTRACT

It is generally known that certain relationships exist between the production of heavy snow and low-level dynamic and thermodynamic parameters, such as vorticity, moisture, and temperature advection patterns. This statistical synoptic climatological study at the 850-mb level is made to understand better these relationships and also to improve operational forecasting of heavy snow over the central and eastern United States. Models relating percentage frequency of heavy snowfall in 12-hr periods to initial and subsequent 850-mb height and temperature patterns are developed. Also, considerable other statistical information is arranged in tabular form for forecaster evaluation.

1. INTRODUCTION

The 850-mb chart long has been a favorite tool of forecasters in forecasting occurrence of precipitation, especially snow. Recently, Hanks et al. (1967) made considerable use of 850-mb observed data in developing a technique for predicting heavy snowfall in the central United States and Spiegler (1969) studied snowfall distribution and frequency about 850-mb cyclones. In view of the pertinence of observational information at this level to forecasting snowfall, data on certain relationships between 850-mb features and occurrence of heavy snowfall have been systematically tabulated and summarized.

2. PROCEDURES

Developmental data consisted of 81 heavy snow occurrences during the 1965-66 and 1966–67 snowfall seasons for the area of the United States east of 100° W., including that portion of Canada south of 49° N. and west of the northern tip of Maine. Complete data for the month of December 1965 were not available; therefore, this month was not included in the study. Heavy snow, as defined in this study, is snowfall of 4 in. or more over a minimum contiguous area of 5 square degrees of latitude (about 17,982 n.mi.^{2}) during the 12-hr periods from 0000 to 1200 GMT or 1200 to 0000 GMT. When an observed heavy snowfall area overlapped the boundaries of the area of interest, the case was used if an importantly large proportion fell within the defined boundaries.

The moving grid was used in relating heavy snowfall to 850-mb synoptic features in a manner similar to that used by Jorgensen (1963) and Fawcett and Saylor (1965). This method related heavy snowfall to the location of the 850-mb low center at the beginning of the snowfall period and its direction of movement during the subsequent 12-hr period—identical to that used by Goree and Younkin (1966) and Younkin (1968) in relating heavy snowfall to 500-mb vorticity maxima. The position of the 850-mb low center served as the basic anchoring coordinate in obtaining relative distribution of heavy snowfall occurrences. The direction of movement was obtained from the observed positions of the Low at the beginning and end of the 12-hr period during which the heavy snow occurred. There was only one instance of heavy snowfall occurrence as defined above in which an 850-mb low center was not discernible.

3. DISCUSSION OF RELATIONSHIPS

Figures 1 and 2 indicate favored locations for occurrence of heavy snowfall in relation to the various parameters at the beginning and end of the snowfall period, respectively. Even though these composite charts show warm advection to be a major contributor to the upward motion producing heavy snow, there is a net slight cooling during the 12-hr period in the region of heavy snowfall.

Tables 1 and 2 give frequency distributions, for the 81 cases, of a number of meteorological measurements. The average direction and speed of movement of the 850-mb low center, 68° at 26 kt, compares with average values for the surface low center of 50° at 31 kt obtained by Goree and Younkin (1966) from an earlier set of data. A northward component in the direction of movement of the 850-mb center was observed in 75 of the 81 cases. Again, this agrees well with the earlier study in that importantly large snowstorms in the central and eastern United States usually move from a southerly direction.

Heavy snow fell during the ensuing 12-hr period at locations with 850-mb temperature as low as −20°C and as high as 5°C. The average temperature at the initial 850-mb low center for all cases was approximately 0°C, while 63 percent of the time this temperature fell between −5°C and 4°C. The 850-mb isotherm that bisected the ensuing heavy snowfall areas averaged approximately −5°C. In 94 percent of the cases, this initial bisecting isotherm was in the −10° to 0°C range.

The average height value of the 850-mb low center at the beginning of the 12-hr snowfall period was 1280 gpm. The central height values varied over a broad range from 1090 to 1470 gpm, with 82 percent of the cases

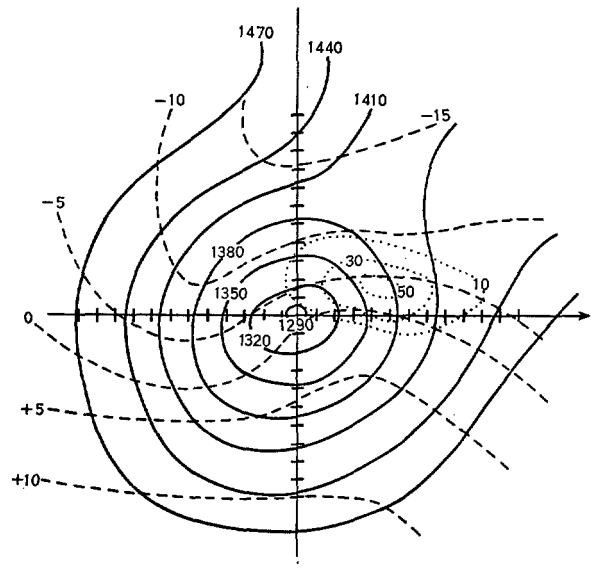

FIGURE 1.—Percentage frequency of occurrence of heavy snow (dotted lines), composite initial 850-mb height (gpm, solid lines) and temperature (°C, dashed lines). Origin is at the position of the 850-mb low center at the beginning of the snowfall period, with horizontal coordinate pointing in the direction of its movement during the following 12 hr. Tick marks on coordinates represent degrees of latitude.

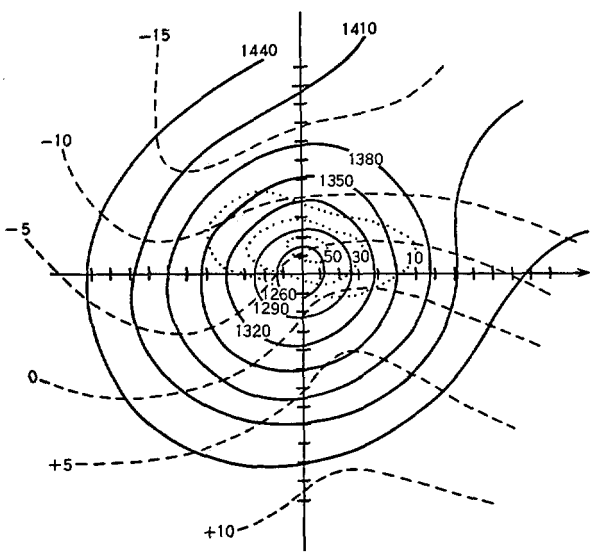

FIGURE 2.—Percentage frequency of occurrence of heavy snow (dotted lines), composite final 850-mb height (gpm, solid lines) and temperature (°C, dashed lines). Origin is at the position of the 850-mb low center at the end of the snowfall period, with horizontal coordinate pointing in the direction of its movement during the preceding 12 hr. Tick marks on coordinates represent degrees of latitude.

falling in the wide interval of 1150 to 1390 gpm. The height contour bisecting the ensuing heavy snowfall area ranged from 1180 to 1540 gpm. The bisecting-contour grouping also had a rather flat distribution pattern, with 67 percent of the cases in the broad range from 1300 to 1440 gpm. Deepening of the 850-mb low center occurred during the 12-hr snowfall period in 94 percent of the cases. The average deepening was approximately 50 gpm.

TABLE 1.—*Frequency distributions, number of cases and percentage frequency of occurrence. Estimated values are from the observed 850-mb charts at the beginning of 12-hr heavy snowfall periods.*

(A) Areal extent (sq deg of lat.) of heavy snowfall cases

	5-9	10-14	15-19	20-24	25-29	30-34	35-40
No. cases	26	18	5	10	14	5	3
Percent	32	22	6	12	17	6	4

(B) Height value (to nearest 10 gpm) of 850-mb low center

	1050-1090	1100-1140	1150-1190	1200-1240	1250-1290	1300-1340	1350-1390	1400-1440	1450-1490
No. cases	1	4	12	12	14	13	15	9	1
Percent	1	5	15	15	17	16	19	11	1

(C) Height contour (to nearest 10 gpm) at 850 mb bisecting heavy snowfall area

	1050-1190	1200-1240	1250-1290	1300-1340	1350-1390	1400-1440	1450-1490	1500-1540
No. cases	1	2	11	14	23	18	9	3
Percent	1	2	14	17	28	22	11	4

(D) Temperature (°C) at 850-mb low center

	-15 to -11	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14
No. cases	3	7	23	28	19	1
Percent	4	9	28	35	23	1

(E) Coldest temperature (°C) at 850 mb over heavy snowfall area

	-20 to -16	-15 to -11	-10 to -6	-5 to -1
No. cases	7	23	35	16
Percent	9	28	43	20

(F) Warmest temperature (°C) at 850 mb over heavy snowfall area

	-10 to -6	-5 to -1	0 to 4	5 to 9
No. cases	6	29	40	6
Percent	7	36	50	7

(G) Isotherm (°C) at 850 mb bisecting heavy snowfall area

	-15 to -11	-10 to -6	-5 to -1	0 to 4
No. cases	4	35	36	6
Percent	5	43	45	7

(H) Direction (to nearest 20° of arc from N.) and distance (deg of lat.) from 850-mb low center to associated surface low center

Distance	30	50	70	90	110	130	150	170	190	210	230	250	310	330	Total
0-1.9	3	2	5	4	6	4	6	5	5	1	1	1	2		45
2.0-3.9	1		3	3	6	6	2	4	1	2	1			1	30
4.0-5.9			1	2		1		1		1					6
No. cases	4	2	9	9	12	11	8	10	6	4	2	1	2	1	81
Percent	5	2	11	11	15	14	10	13	8	5	2	1	2	1	100

(I) Temperature (°C) at 850 mb over associated surface low center

	-10 to -6	-5 to -1	0 to 4	5 to 9	10 to 14
No. cases	3	12	23	26	17
Percent	4	5	28	32	21

TABLE 2.—*Frequency distributions, number of cases and percentage frequency of occurrence. Average values are from the two 850-mb charts at the beginning and ending of the 12-hr heavy snowfall periods.*

(A) Speed of movement (kt) of 850-mb low center

	5–9	10–14	15–19	20–24	25–29	30–34	35–40	41–45	46–50	51–55	56–60
No. cases	5	6	13	12	15	11	11	3	0	3	1
Percent	6	7	16	15	19	14	14	4	0	4	1

(B) Direction of movement (toward and to nearest 10° of arc from N.) of 850-mb low center

	10	20	30	40	50	60	70	80	90	100	110	120	130	300	340
No. cases	4	3	4	9	11	12	19	4	4	3	4	1	1	1	1
Percent	5	4	5	11	14	15	23	5	5	4	5	1	1	1	1

(C) Intensity (gpm) of 850-mb low center—outermost closed height contour (10 gpm) minus central height value (to nearest 10 gpm)

	<50	50–90	100–140	150–190
No. cases	7	33	33	8
Percent	8	41	41	10

The position of the surface low center was recorded for each case; consequently, the slope from the 850-mb low center is included in table 1. Generally, the least slope between the surface low center and associated 850-mb low center occurred during the initial stages of extensive snowfall and when the systems were at lower latitudes. The average slope was 1:125, while the extreme slope was 1:300. The direction of the surface low center from the 850-mb center had a southerly component in all cases except three. In 60 percent of the cases, the surface low center was in the southeast quadrant of the 850-mb Low.

The 850-mb temperature over the surface low center is given in table 1. Since the main moisture inflow with consistently high relative humidity occurs aloft near the position of the surface low center, this temperature information was used to provide an indication of moisture inflow into the system without reference to specific moisture measurements, such as precipitable water, dew points, etc. Also, 850-mb temperature forecasts are available at many Weather Bureau Offices and can be used to infer this parameter. During 53 percent of the time, the 850-mb temperatures over the surface low center at initial time were in the 5° to 14°C range, and 81 percent of the time they were 0°C or higher.

The extent of an analyzed area of observed heavy snowfall in a specific 12-hr period depends also upon factors other than rate of fall and duration: for example, warmth of the ground, time of onset of snowfall within the period, and density of observational network. However, above and beyond these and other meteorologically disturbing factors, there is a sufficiently close relationship between the strength of the 850-mb Low and areal extent of heavy snow to be of some aid in forecasting. A crude measure of the average strength of the 850-mb Low (sum in decameters of the outermost closed contour at the beginning and end of the snowfall period minus central values) minus 6 decameters provides a rough guide as to reasonable extent of snowfall in a 12-hr period in square degrees of latitude.

4. SUMMARY

1) The mean circulation of the 850-mb Lows increased significantly during the 12-hr period of heavy snowfall. Computations of geostrophic relative vorticity (849-km grid) from the composite charts (figs. 1 and 2) yield an increase of 13 percent at the low center. However, at the center of highest percentage occurrence of heavy snow, the increase was nearly fourfold.

2) The highest probability of heavy snow lies approximately 90 n.mi. to the left of the track of the 850-mb low center.

3) Cooling in the rear quadrants of the Low occurs in early stages of development. In the front quadrants of the Low, little warming occurs in spite of substantial warm advection. Apparently, upward motion and precipitation cooling offset advection and latent heat warming.

4) On the average, the initially observed −5°C isotherm nearly bisects the observed subsequent 12-hr heavy snowfall area.

5) The direction of movement of 850-mb low centers during heavy snowfall from a northerly component is an infrequent occurrence.

6) The initially observed 850-mb temperature over the surface low center is above 0°C most of the time when heavy snow occurs during the subsequent 12 hr.

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